Check List the journal of biodiversity data

LISTS OF SPECIES

Check List 12(2): 1863, 24 March 2016 doi: http://dx.doi.org/10.15560/12.2.1863
ISSN 1809-127X

Small mammals from Miri, northeastern region of Sarawak, Malaysian Borneo: note on new locality records

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Abstract: Small mammal surveys were conducted at Niah National Park, Lambir Hills National Park and Gunung Mulu National Park, Miri Division, in the northeastern region of Sarawak, using ground-level and canopy mist-nets, harp traps, and cage traps. The main objective of these surveys was to assess small mammal diversity in the northeastern region of Sarawak. Gunung Mulu National Park recorded the highest diversity of small mammals with 29 species, followed by Niah National Park with 19 species, and Lambir Hills National Park, 17 species. These surveys revealed nine new locality records for Miri, including eight bat species (*Dyacopterus spadiceus, Megaerops wetmorei, Nycteris tragata, Hipposideros cineraceus, Hesperoptenus blanfordi, Kerivoula pellucida, Murina suilla* and *Myotis muricola*) and a squirrel (*Sundasciurus brookei*). *Megaerops wetmorei* is also reported for the first time in Sarawak.

Key words: Borneo; diversity; Chiroptera; Rodentia; Scandentia

INTRODUCTION

Borneo hosts a rich small mammal fauna, including at least 186 species from the orders Chiroptera, Dermoptera, Pholidota, Rodentia, and Scandentia (Payne et al. 1985). Although several studies have been conducted on these faunas in Sarawak (e.g., Jayaraj et al. 2005; Khan et al. 2006; Khan et al. 2008; Mohd-Azlan et al. 2005; Mohd-Ridwan et al. 2011; Jayaraj et al. 2011; McArthur 2012; Azhar et al. 2013), their occurrence in the northeastern division of this state remains poorly known. With an area of approximately 26,777 km^2, the city of Miri, which is located in the northeastern part of Sarawak, harbors eight out of the 25 national parks (NP) found in this state. Miri also holds a wide range of habitats, from hill dipterocarp forest to karstic areas.

The Melinau Limestone Formation, in Gunung Mulu NP, extends 38 km in length and 8 km in width, and is one of the largest limestone massifs in the world, acting as a boundary between Miri and Limbang divisions in Sarawak (Wilford 1964). This karstic environment contains more than 10 caves, including Deer Cave, Lagang Cave, and the world's largest chamber, Sarawak Chamber. Niah Cave, in Niah NP, serves as the main habitat for swiftlets and bat species within the national park area (Medway 1997). In this study, we present results from surveys carried out at Niah NP, Lambir Hills NP, and Gunung Mulu NP.

Surveys in protected areas are crucial for conservation and management purposes, particularly in regions experiencing prominent rates of deforestation (Fuller et al. 2004; Sodhi et al. 2004; Curran et al. 2004; Sodhi and Brook 2006). It has been suggested that if the current deforestation pace continues, approximately 40% of the bat species within Southeast Asia will be extinct by the end of this century (Kingston 2010). Thus, there is a need to document species distribution in this region, especially in areas identified as biodiversity hotspots, like Borneo, where information on small mammals is still scarce.

MATERIALS AND METHODS

Sampling sites

Surveys were conducted in three national parks in the Miri Division of Sarawak (Figure 1). Permission to conduct

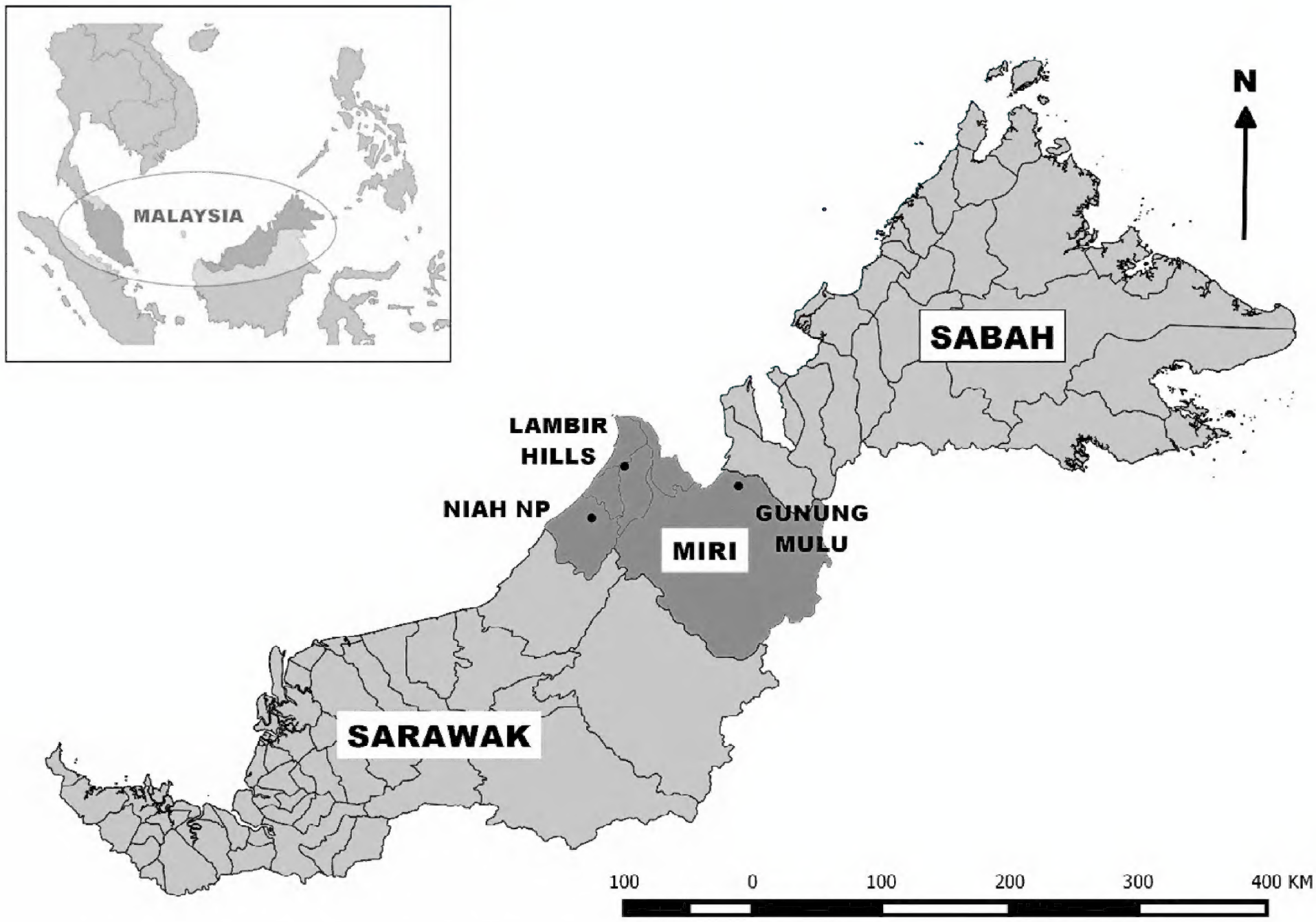

Figure 1. Map showing the study sites in Miri, Sarawak, Malaysia Borneo.

research on wildlife was provided by Sarawak Forestry Corporation. Niah NP (03°47′53.3″ N, 113°47′12.8″ E) is located about 110 km southwest of Miri (Hazebroek and Abang-Morshidi 2000) and comprises 3,140 hectares (ha) of sub-coastal lowland mixed dipterocarp forest and limestone hills. The sampling areas were located at Lobang Gan Kira, one of the entrances of Niah Great Cave, and along Madu Trail, within the park. Limestone forest surrounds Lobang Gan Kira, whereas Madu Trail is in the midst of a mixed dipterocarp forest. *Ficus* spp. (Moraceae), *Dipterocarpus* spp. (Dipterocarpaceae), *Cosmianthhemum* spp. (Acanthaceae), *Goniothalamus* spp. (Annonaceae), *Calamus* sp. (Arecaceae), *Begonia* spp. (Begoniaceae), *Macaranga* spp. (Euphorbiaceae), and *Semecarpus rufovelutinus* (Anacardiaceae), as well as other species of palm and orchids are present in the forest area (Pearce 2004).

Lambir Hills NP (04°11′54.1″ N, 114°02′34.3″ E) consists of complex and diverse forest systems with a total area of 6,952 ha. The park's vegetation includes mixed dipterocarp forests and heath forests. Sampling was conducted outside the main area of the park (52 ha plot trail), in an area covered by mature lowland mixed dipterocarp forest. The forest community is dominated by *Koilodepas longifolium* (Euphorbiaceae), *Millettia vasta* (Leguminosae), *Dryobalanops lanceolata* (Dipterocarpaceae), and *Hopea dryobalanoides* (Dipterocarpaceae) (Lee et al. 2002).

Gunung Mulu NP (04°02′45.0″ N, 114°55′57.8″ E) is a World Heritage Area comprising 52,864 ha and 17 types of vegetation. Due to the huge area, many sites in the park, such as Camp 5 (situated in the northeastern part), remain scarcely studied (Azhar et al. 2013). We surveyed the western part of the park, which is covered with peat swamp, riverine, and limestone forests.

Field methods and specimen processing

An average of five 4-shelf mist nets, four 4-bank harp traps, one high pole 10-shelf mist net (7.3 m tall), and 100 cage traps were set at each sampling night, and we spent five nights at Niah NP, four at Lambir Hills, and 12 at Gunung Mulu. Mist nets were erected at potential flight pathways of bats and harp traps were set crossing narrow pathways and along a river. High nets were set up at sub-canopy level to target high-flying bats. Mist nets and harp traps were checked every 15–30 minutes, from 18:30 h – 21:30 h. Harp traps were kept open until the following morning and checked again at 06:30 h, if there was no rain on that particular day. Mist nets and harp traps were set up at different locations within the sampling areas during the period of study to maximize the effort to cover the areas. Cage traps were set at a distance of 5 m from one another along a forest transect and checked twice each day; once in the morning (10:00

h) and once in the evening (16:00 h), and re-baited if necessary. Banana, pineapple, sweet potato, and salted fish were used as baits for the cage traps.

Captured individuals were identified following Payne et al. (1985). Standard external measurements and weight were recorded for each captured individual. The external body measurements were taken using electronic digital caliper and the body weight was recorded using a Pesola spring balance. Selected specimens were prepared as museum vouchers, and those also representing new locality records had their skulls extracted and cleaned.

External and skull measurements

Skull measurements were taken following Kitchener and Maryanto (1995) and Jayaraj (2008), using electronic digital caliper with the aid of magnifying glass.

Overall, 19 external and 17 skull and dental measurements were obtained for bats (FA, forearm length; E, ear length; TR, tragus; TB, tibia length; HF, hindfoot length; HB, head and body length; T, tail length; TL, total length; WT, weight; D2MCL, second digit metacarpal length; D3MCL, third digit metacarpal length; D3P1L, third digit first phalanx length; D3P2L, third digit second phalanx length; D4MCL, fourth digit metacarpal length; D4P1L, fourth digit first phalanx length; D4P2L, fourth digit second phalanx length; D5MCL, fifth digit metacarpal length; D5P1L, fifth digit first phalanx length; D5P2L, fifth digit second phalanx length; GSL, greatest skull length; IOW, interorbital width; CW, cranial width; MW, mastoid width; ZW, zygomatic width; PL, palatal length; PPL, post-palatal length; BL, bulla length; DBC, distance between cochleae; GBPL, greatest basial pit length; DL, dental length; C1BW, first canine breadth; C1C1B, breadth across canines; M3M3B, breadth across molars; C1M3L, maxillary tooth row length; M2L, second molar length; and M2W, second molar width).

Rodentia skull measurements were taken according to Nagorsen and Peterson (1980). Overall, six external and 23 skull and dental variables were measured for rodents (E, ear length; HF, hindfoot length; HB, head and body length; T, tail length; TL, total length; WT, weight; GSL, greatest skull length; POW, post orbital width; BoZP, breadth of zygomatic plate; IOB, interorbital breadth; NL, nasal length; NW, nasal width; BB, breadth of braincase; BH, braincase height; DL, length of diastema; PL, palatal length; UMR, upper molar tooth row; IFL, length of incisive foramina; IFB, breadth of incisive foramina; M1W, upper molar 1 width; M2W, upper molar 2 width; M3W, upper molar 3 width; M1M1, distance of right-left upper molar 1; M2M2, Distance of right-left upper molar 2; M3M3, distance of right-left upper molar 3; BL, bulla length; MSW, mesopterygoid fossa width; RAP, ramus angular process; MaL, length of mandible).

Specimens were prepared as either wet or dry museum specimens. All the specimens were deposited in the Universiti Malaysia Sarawak (UNIMAS) Zoological Museum, and the taxonomic nomenclature adopted is based on Corbet and Hill (1992) as well as Wilson and Reeder (2005).

Statistical analyses

Number of captures was used to calculate the relative abundance of each species, and species accumulation curves were constructed by taking the number of survey nights as sampling unit. We selected two non-parametric estimators, ACE (Abundance Coverage-based Estimator) and Chao 1, to generate more accurate assessments of the completeness of our surveys, assuming that both estimators evaluate the species richness from each site when their values are not substantially different (Hortal et al. 2006). Considering the unequal effort applied to each site, we also used rarefaction curves to perform intersite comparisons of species richness. Due to low capture numbers, particularly at Niah and Lambir Hills, non-volant small mammals were excluded from this latter analysis. Curves were generated based on species richness and number of individuals recorded for each species. The analyses were performed using EstimateS, version 9.10 (Colwell 2013).

RESULTS

Species list and abundance

A total of 216 individuals comprising 41 species of small mammals were captured at the three national parks in Miri. We recorded 32 species from the order Chiroptera, six from Rodentia, two from Scandentia, and one from Pholidota. The number of species ranged from 19 at Niah NP to 29 at Gunung Mulu NP (Tables 1 and 2).

The most abundant volant species caught in Miri (for all sampling areas) was *H. cervinus* (Gould, 1863) (13.80%), followed by *Hipposideros galeritus* Cantor, 1846 (11.34%), *Balionycteris maculata* (Thomas, 1893) (11.34%), and *Rhinolophus creaghi* Thomas, 1896 (7.89%). *Sundamys muelleri* (Jentink, 1879) was the most dominant non-volant species caught in Miri (19.05%). Seven species were captured as singletons: *Dyacopterus spadiceus* (Thomas, 1890), *Megaerops wetmorei* Taylor, 1934, *Eonycteris spelaea* (Dobson, 1871), *Hesperoptenus blanfordi* (Dobson, 1877), *Miniopterus australis* (Tomes, 1858), *Sundasciurus brookei* (Thomas, 1892), and *Manis javanica* Desmarest, 1822 (Tables 1 and 2).

New locality records and species identification

Nine species reported here represent new locality records (Tables 3 and 4; Figure 2), including, *H. blanfordi* and *Murina suilla* (Temminck, 1840), both sampled at Niah NP. Diagnostic characters described for all these species by Payne et al. (1985) and found in our specimens are as follows. In *Hesperoptenus blanfordi* a pad is present in both thumb and foot, and the thumb pad is slightly

Table 1. List of chiropteran species found at three national parks in Miri, Sarawak, Malaysia Borneo, with number of captures, general relative abundance, and conservation status based on IUCN (2015).

	Niah	Lambir Hills	Gunung Mulu	Relative Abundance (%)	IUCN
Pteropodidae					
Cynopterus brachyotis (Müller, 1838)	2	1	6	4.44	LC
Cynopterus horsfieldi Gray, 1843			5	2.47	LC
Penthetor lucasi (Dobson, 1880)	1		5	2.96	LC
Dyacopterus spadiceus (Thomas, 1890)			1*	0.49	NT
Balionycteris maculata (Thomas, 1893)	3	5	15	11.34	LC
Megaerops wetmorei Taylor, 1934			1**	0.49	V
Eonycteris spelaea (Dobson, 1871)		1		0.49	LC
Macroglossus minimus (E. Geoffroy, 1810)		1	2	1.48	LC
Megadermatidae					
Megaderma spasma (Linnaeus, 1758)			2	0.99	LC
Nycteridae					
Nycteris tragata (K. Andersen, 1912)	1		1*	0.99	NT
Rhinolophidae					
Rhinolophus philippinensis Waterhouse, 1843	5		2	3.45	LC
Rhinolophus creaghi Thomas, 1896	1		15	7.89	LC
Rhinolophus borneensis Peters, 1861	10	2	3	7.40	LC
Rhinolophus sedulus K. Andersen, 1905		2		0.99	NT
Hipposideridae					
Hipposideros diadema (E. Geoffroy, 1813)	1		6	3.45	LC
Hipposideros dyacorum Thomas, 1902		9	1	4.93	LC
Hipposideros ater Templeton, 1848	5			2.47	LC
Hipposideros cineraceus Blyth, 1853	1	1*		0.99	LC
Hipposideros ridleyi Robinson and Kloss, 1911		6		2.96	V
Hipposideros galeritus Cantor, 1846	3		20	11.34	LC
Hipposideros cervinus (Gould, 1863)	3	13	12	13.80	LC
Coelops robinsoni Bonhote, 1908	2			0.99	V
Vespertilionidae					
Vespertilioninae					
Myotis muricola (Gary, 1864)			2*	0.99	LC
Myotis horsfieldii (Temminck, 1840)	1		3	1.97	LC
Hesperoptenus blanfordi (Dobson, 1877)	1*			0.49	LC
Murininae					
Murina suilla (Temminck, 1840)	1*			0.49	LC
Kerivoulinae					
Kerivoula papillosa (Temminck, 1840)	1	2	4	3.45	LC
Kerivoula hardwickii (Horsfield, 1824)		2	1	1.48	LC
Kerivoula pellucida (Waterhouse, 1845)		2	2*	1.97	NT
Kerivoula minuta Miller, 1898		1		0.49	NT
Miniopterinae					
Miniopterus australis Tomes, 1858			1	0.49	LC
Molossidae					
Chaerophon plicatus (Buchana, 1800)			3	1.48	LC
Total individual	**42**	**48**	**113**		
Total species	**17**	**14**	**23**		
Total families	**5**	**4**	**6**		
Total new locality record for sampling area	**2**	**1**	**5**		
Total new records for Sarawak	**0**	**0**	**1**		

LC (Least Concern), V (Vulnerable), NT (Near Threatened)
* New locality records
**New locality record for Sarawak

triangular in shape and smaller than in other species in Borneo that have thumb pads (e.g., bamboo bats: *Glischropus* and *Tylonycteris*). In *M. suilla*, nostrils are tubular and elongated (unique for the genus), and fur is bright orange with dark base at dorsum and similar in color, but more greyish, ventrally (unique for the species). The single new record from Lambir Hills NP, *H. cineraceus* (Blyth, 1853), lacks lateral leaflets and can be discriminated from species of the *Hipposideros bicolor* group through its simple noseleaf and medially expanded internarial septum.

Most new locality records from our surveys were

Table 2. List of non-volant mammals found at three national parks in Miri, Sarawak, Malaysia Borneo, with number of captures, general relative abundance, and conservation status based on IUCN (2015).

	Niah	Lambir Hills	Gunung Mulu	Relative Abundance (%)	IUCN
SCANDENTIA					
Tupaiidae					
Tupaia picta Thomas, 1892		1	2	14.29	LC
Tupaia tana Raffles, 1821		3		14.29	LC
RODENTIA					
Sciuridae					
Sundasciurus brookei (Thomas, 1892)			1*	4.76	LC
Muridae					
Rattus argentiventer (Robinson and Kloss, 1916)			2	9.52	LC
Rattus exulans (Peale, 1848)	2			9.52	LC
Sundamys muelleri (Jentink, 1879)			4	19.05	LC
Niviventer cremoriventer (Miller, 1900)	2			9.52	V
Leopoldamys sabanus (Thomas, 1887)			3	14.29	LC
PHOLIDOTA					
Manis javanica Desmarest, 1822			1	4.76	NT
Total individual	**4**	**4**	**13**		
Total species	**2**	**2**	**6**		
Total families	**1**	**1**	**4**		
Total new distributional record for sampling area	**0**	**0**	**1**		

LC (Least Concern), V (Vulnerable), NT (Near Threatened)
* New locality records

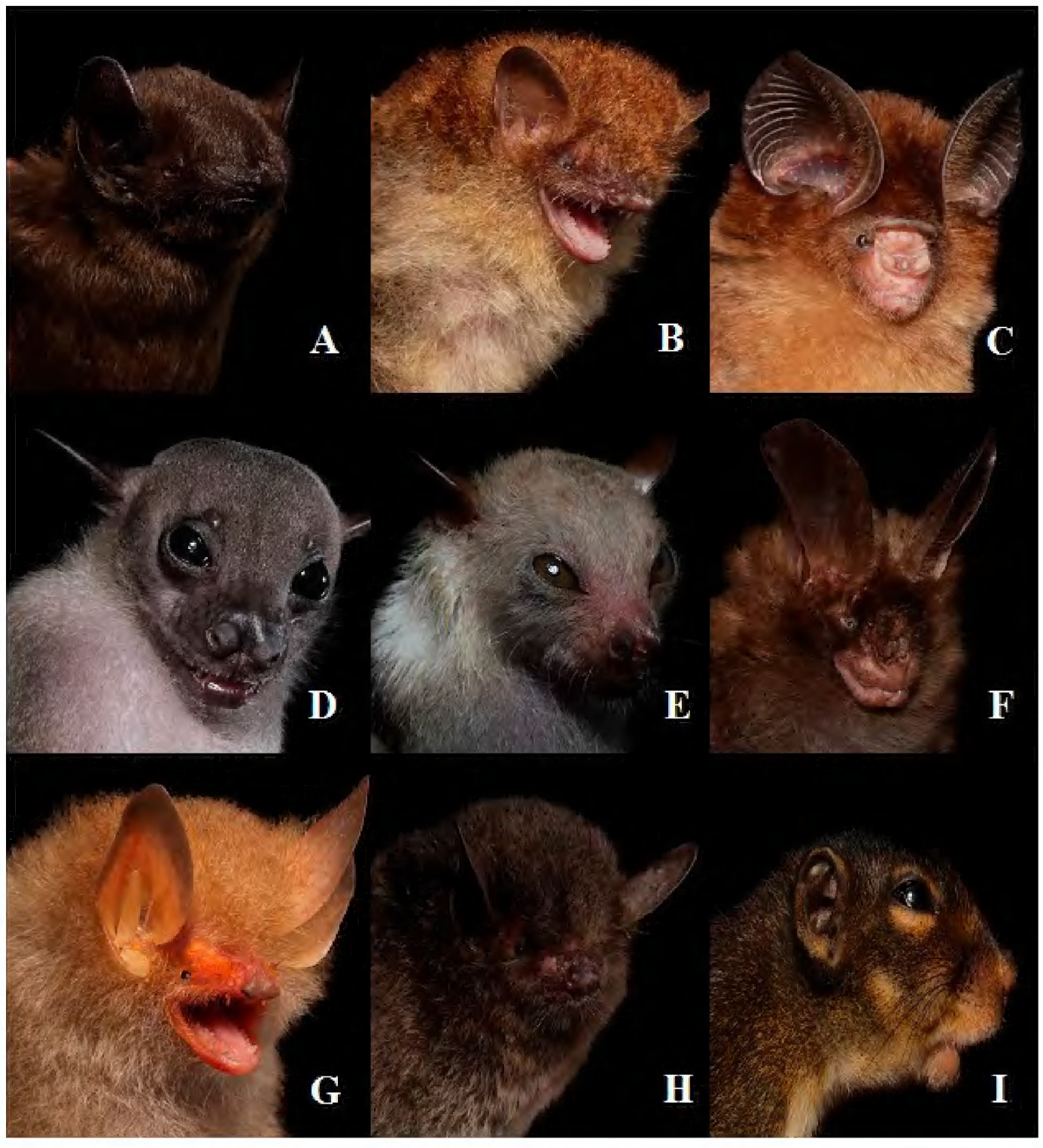

Figure 2. Live photographs of small mammals recorded for the first time in Miri, Sarawak, Malaysia Borneo. *Hesperoptenus blanfordi* (NNP14-016; A) and *Murina suilla* (NNP14-008; B) are new locality records for Niah National Park; *Hipposideros cineraceus* (LHNP14-016; C) is a new record for Lambir Hills National Park; and *Dyacopterus spadiceus* (MNP14-109; D), *Megaerops wetmorei* (MNP14-071; E), *Nycteris tragata* (MNP14-031; F), *Kerivoula pellucida* (MNP14-111; G), *Myotis muricola* (MNP14-076; H), and *Sundasciurus brookei* (MNP14-042; I) are new records for Gunung Mulu National Park.

Table 3. External and skull measurements of specimens representing new locality records of bats for Miri, Sarawak, Malaysia Borneo.

Variables	*Dyacopterus spadiceus* MNP14-109 (♀)	*Megaerops wetmorei* MNP14-071 (♂)	*Nycteris tragata* MNP14-031 (♀)	*Hipposideros cineraceus* LHNP14-016 (♀)	*Myotis muricola* MNP14-076 (♂)	*Hesperoptenus blanfordi* NNP14-016 (♂)	*Murina suilla* NNP14-008 (♂)	*Kerivoula pellucida* MNP14-111 (♂)
FA	77.6	46.0	51.7	35.4	35.6	25.5	29.6	28.3
EAR	16.8	11.5	27.5	15.8	10.4	9.1	9.2	14.8
TR	-	-	-	-	5.9	3.0	3.8	7.7
TB	29.7	17.5	28.9	15.1	14.9	10.5	14.8	15.7
HF	16.0	9.6	8.1	5.9	5.6	5.4	6.1	6.0
T	26.0	-	74.0	25.0	39.0	23.7	30.0	48.0
HB	150.0	62.0	57.0	38.0	38.0	43.3	41.0	38.0
TL	176.0	62.0	131.0	63.0	77.0	67.0	71.0	86.0
WT	70.0	12.0	27.0	6.0	3.5	-	3.5	9.0
D2MCL	39.9	28.1	35.7	29.4	31.0	22.4	25.2	34.2
D3MCL	56.3	32.0	34.2	26.6	33.6	22.4	25.8	33.1
D3P1L	37.3	21.9	20.9	14.8	14.4	12.3	12.1	15.6
D3P2L	39.0	26.1	23.3	12.8	17.1	7.4	14.7	21.9
D4MCL	54.1	30.1	38.2	29.0	33.0	22.0	24.6	31.6
D4P1L	30.9	17.7	9.7	9.0	8.7	11.9	7.9	12.2
D4P2L	24.6	13.7	7.9	6.7	9.4	4.8	6.2	7.0
D5MCL	55.2	31.0	40.2	27.6	31.1	21.1	25.1	30.4
D5P1L	24.8	14.1	10.5	11.4	9.5	7.6	7.9	10.5
D5P2L	20.8	13.6	8.9	9.0	7.5	4.5	7.8	6.8
GSL	13.9	21.1	22.6	14.5	14.2	12.6	15.3	13.9
IOW	3.1	4.7	6.2	2.7	3.6	4.6	4.3	3.1
CW	-	-	8.7	-	-	-	-	-
MW	6.7	5.3	9.1	6.1	5.7	6.1	5.5	6.7
ZW	6.9	9.8	13.6	7.6	6.4	7.0	7.0	6.9
PL	8.4	8.5	8.6	7.5	8.4	7.3	6.4	8.4
PPL	7.0	11.5	8.3	6.3	6.5	5.0	8.9	7.0
DBC	5.2	7.3	3.9	5.3	5.1	5.5	5.4	5.2
BL	2.6	3.6	2.5	3.5	3.1	3.2	2.8	2.6
GBPL	2.4	1.9	5.7	2.0	1.7	2.1	1.3	2.4
DL	2.5	3.7	15.8	3.0	3.4	1.8	1.6	2.5
C1BW	10.2	16.8	1.6	9.1	10.5	8.8	11.2	10.2
C1C1B	0.7	1.3	5.5	1.0	0.8	0.8	0.8	0.7
M3M3B	3.2	4.6	8.5	2.9	2.4	3.8	2.9	3.2
C1M3L	5.0	6.4	8.2	5.7	5.9	6.5	5.6	5.0
M2L	6.4	1.3	1.6	5.0	6.3	4.0	6.2	6.4
M2W	1.1	1.3	1.9	0.8	1.1	0.8	1.1	1.1

found at Gunung Mulu NP, including *S. brookei* and five bat species: *D. spadiceus, M. wetmorei, Nycteris tragata* (K. Andersen, 1912), *Myotis muricola* (Gray, 1964), and *Kerivoula pellucida* (Waterhouse, 1984). *Dyacopterus spadiceus* can be distinguished from other fruit bats in Borneo by its short muzzle with massive square cheek teeth and powerful jaw. The other fruit bat representing a new locality record for the park, and also for Sarawak, is *M. wetmorei*, which can be discriminated from other fruit bats based on the presence of white tufts on both sides of the neck, extending to the back (Figure 3). This species is also characterized by presenting no tail, short muzzle, and one pair of lower incisors. External and skull measurements of our adult male specimen (Table 3) match those previously reported from Brunei by Payne et al. (1958) (e.g., FA = 46; E = 12; Wt = 14). Bats identified as *N. tragata* can be easily recognized by the presence of a deep hollow groove in the middle of the face, fringed with large flaps that form a type of noseleaf. Further, this species can be discriminated from their congeners in Southeast Asia based on their T-shaped tail tip. Although *M. muricola* is currently recognized as a species complex, we tentatively identified our specimen in this taxon based on a combination of both external and cranial characters, as follows: small feet and wing membrane attached at base of toes (diagnostic characters of members of subgenus *Selysius*); forearm size ranging from 33 to 37 mm; ears moderately long, with a slender tragus, bent forward, and bluntly pointed; and middle upper premolars small and slightly intruded from the tooth row. *Kerivoula pellucida* can be recognized by its almost translucent wing membranes, also presenting

Table 4. External and skull measurements of a male *Sundasciurus brookei* from Miri, Sarawak, Malaysia Borneo.

Variables	*Sundasciurus brookei* MNP14-042 (♀)
E	14.9
HF	37.9
HB	162.0
T	125.0
TL	287.0
WT	140.0
GSL	4.1
POW	1.7
BoZP	0.3
IOB	0.9
NL	1.3
NW	0.4
BB	1.5
BH	1.8
DL	1.0
PL	1.8
UMR	0.8
IFL	0.4
IFB	0.1
M1W	1.9
M2W	2.0
M3W	2.1
M1M1	5.2
M2M2	5.2
M3M3	5.6
BL	1.2
MSW	0.3
RAP	8.0
MaL	21.0

dorsal fur pale orange-brown, with paler grey bases, and ventral fur greyish-white. The single non-volant species representing a new locality record, the squirrel *S. brookei*, can be identified by its greyish underparts (ventral fur also presenting whitish tips) and by the presence of a reddish patch between hind legs.

Sampling analyses

Based on the species accumulation curves, which did not yet reach an asymptote (Figure 4), we can expect that additional species will be discovered at the three national parks. The non-parametric estimator ACE showed a completeness of 80% for Niah, 69% for Lambir Hills, and 85% for Gunung Mulu NP (Figure 4). Another non-parametric estimator, Chao 1, estimated 83%, 66%, and 85% for Niah, Lambir Hills, and Gunung Mulu NP, respectively (Figure 4). These results showed an acceptable estimate according to the sampling efforts for Niah and Gunung Mulu NP. Although we found a larger number of bat species at Gunung Mulu NP (23 vs. 17 at Niah and 14 at Lambir Hills), intersite comparisons based on rarefaction curves revealed no statistical differences in species richness (Figure 5).

DISCUSSION

Volant species diversity

Previous bat studies in Miri listed 38 species for Niah NP (Mohd-Ridwan et al. 2010), 29 for Lambir Hills (Jayaraj et al. 2011), and 44 for Gunung Mulu NP (McArthur 2012; Azhar et al. 2013). Results from the present study showed that at least two additional species occur at Niah NP, one at Lambir Hills NP, and five at Gunung Mulu NP. The increase in the number of species caught in those areas are possibly due to the amount of effort made to cover all possible areas and the usage of more effective traps such as the harp trap (Francis 1989a) and the high net to target the high flying bats. The use of these traps, especially the high nets, were lacking in some of the previous studies reported here. The additional species in each park were mostly

Figure 3. *Megaerops wetmorei* captured at Gunung Mulu NP, Sarawak, Malaysia Borneo. This adult male has white tufts on both sides of its neck, extending also onto its back to form a broken collar.

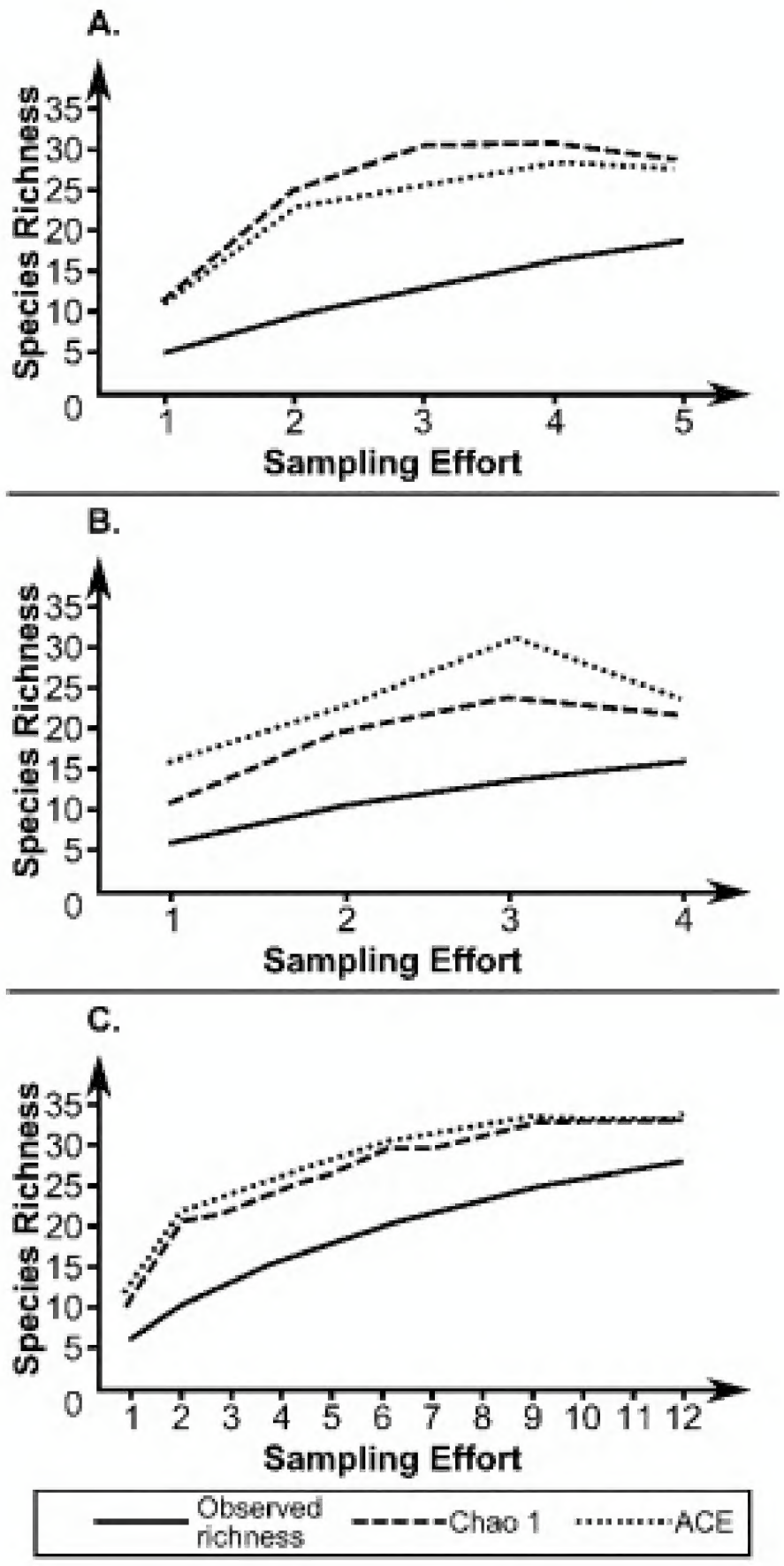

Figure 4. Species accumulation curves for small mammals as a function of sampling nights at Niah (A), Lambir Hills (B), and Gunung Mulu (C) National Parks, Miri, Sarawak, Malaysia Borneo.

captured using harp traps (*H. cineraceus*, *N. tragata*, *H. blanfordi*, *K. pellucida*, *M. muricola*, and *M. suilla*), whereas *D. spadiceus* and *M. wetmorei* were captured using high nets.

Most bat species captured in Miri are insectivorous (74%), which is probably related to the placement of nets and traps at ground level (except for a single higher, 7.3 m tall net). These bats are known to forage at the understorey in lowland forests, usually in groups (Payne et al. 1985). Fruit-eating bats, on the other hand, are more prone to be captured at the upperstorey, where more fruits are available (e.g., Francis 1990). Hipposideridae, Pteropodidae, and Rhinolophidae were the most abundant families caught at all three sampling sites.

The existence of limestone forests at Niah NP and Gunung Mulu NP explains the abundance of cave-dwelling species reported in this study, such as *H. diadema* (3.45%), *Penthetor lucasi* (2.96%), and *R. creaghi* (7.89%). Twenty of the bat species captured at these parks are known as cave-dwellers (63% of all species captured). Caves provide an isolated habitat where bats can roost and protect themselves from adverse weather and environments, and also offer a secure place to mate, rear their young, and interact with conspecifics and other species (Kunz 1982). Cave bats play their own ecological role in the limestone karst areas that they inhabit. They act as pollinators, provide energy in the cave ecosystem in the form of guano, and serve as pest controllers (Payne et al. 1985; Tan et al. 1998).

This survey revealed the presence of *M. wetmorei* at Gunung Mulu NP, showing that this park harbors species not commonly found elsewhere in Borneo. This poorly known Malaysian fruit bat was previously not known to inhabit Sarawak, although a bat from this particular species was first recorded in Brunei, Borneo (Francis 1989b; Payne et al. 1985). The *M. wetmorei*

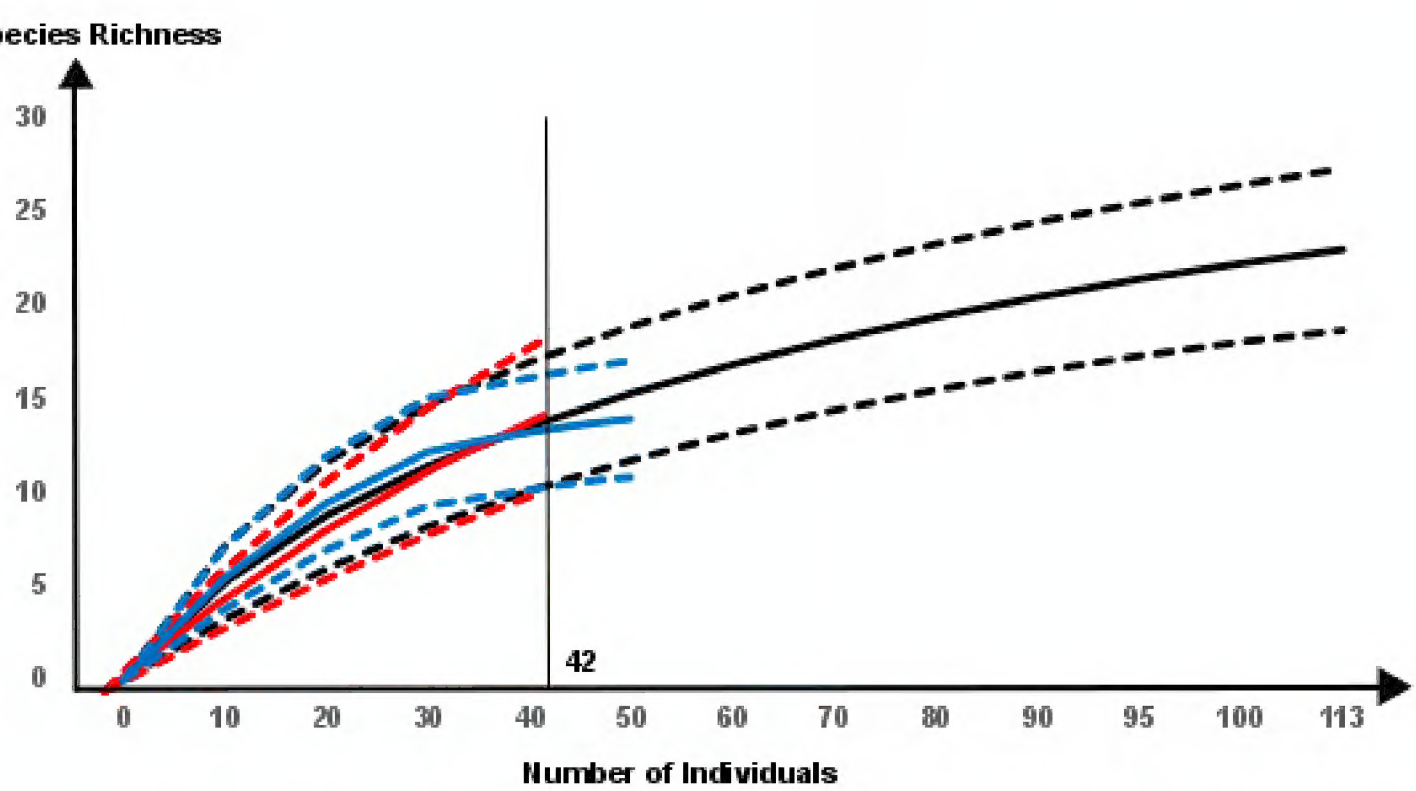

Figure 5. Individual-based rarefaction curves (solid lines) for bats sampled at Niah (red), Lambir Hills (blue), and Gunung Mulu (black) National Parks, Miri, Sarawak, Malaysia Borneo, with 95% confidence intervals (dashed lines). The vertical line shows the species richness when 42 individuals were sampled at the three sites.

specimen was captured in a high-net that was set along the Sungai Lupar Bridge. This species is known to forage at the canopy level (Kingston et al. 2006).

Non-volant diversity

The Gunung Mulu NP is a new locality record for the Bornean endemic *S. brookei*. This species is only known from very few primary forests (Saiful et al. 2001; Wells et al. 2004), including Gunung Penrissen, Gunung Dulit, Usun Apau, Batu Sungai Song, and Long Akah in Sarawak (Yasuma et al. 2003). The reason for the low number of captured individuals for non-volant species, especially for Niah and Lambir Hills NP, is unclear. Nonetheless, the shorter sampling periods at both Niah and Lambir NP, together with seasonal variation in the abundance of certain small mammal species, could contribute to the observed low capture rate. Further, only cage traps were used to capture all the non-volant species, probably limiting our capture success (Maklarin 1998). Use of different traps such as the Sherman traps, pit fall traps, and snap traps in these sites may increase the capture rates and provide better representation of non-volant small mammal diversity in these parks.

Conclusion

Niah, Lambir Hills, and Gunung Mulu National Park support high diversity of small mammals, especially bats, and there is a high possibility that additional species will be recorded in these areas in the future. This is evident from our species accumulative curves (Figure 4), all of which are yet to reach asymptote. These data highlight the necessity of further samplings in Miri, and also of a continued effort to conserve this region and its mammalian fauna.

ACKNOWLEDGEMENTS

We would like to express our greatest gratitude to UNIMAS for awarding the Zamalah Vice Chancellor Research Award 2013. The funding for this study also came from four grants, namely RAGS/STWN10 (5)/1046/2013(13), RAGS/g (4)/916/2012 (17), RACE/g (2)/1107/2013(15), and 01(S130)/1024/2013(14) awarded to RCTT, MRAR, FAAK, and MZK respectively. Our heartfelt thanks goes to the Sarawak Forestry Department for granting research permits. We also extend our gratitude to the Park Wardens, Park Managers and staff members at Lambir Hill NP, Niah NP and Mulu NP for their kind assistance. Last but definitely not least, special thanks to Prof. Dato' Dr. Mohd Tajuddin Abdullah for his thoughtful comments and guidance throughout this study.

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Author contributions: SPHR, NFDAT, RF, NAL, NMN, IA, collected the data (include sampling, skull extraction); EMA collected the data (sampling); MZK, MRAR, FAAK, and RCTT collected the data and contributed ideas in writing the article.

Received: 13 March 2015
Accepted: 7 March 2016
Academic editor: Marcelo R. Nogueira